REWORKED DEVONIAN (GIVETIAN–FRASNIAN) SPORES FROM A PERMIAN GLACIALLY-DERIVED SEQUENCE AT BACCHUS MARSH, VICTORIA

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Emphanisporites rotatus McGregor emend. McGregor 1973 is a distinctive Devonian spore with a known primary source age range in Australia spanning the upper Givetian to early Frasnian (Middle to Late Devonian). This is the first record of the species from Victoria. It occurs as a reworked element in an Early Permian assemblage belonging to the *Granulatisporites confluens* Zone derived from glacigene diamictite in the Bacchus Marsh area. As the predominant direction of Permian ice movement recorded in the Bacchus Marsh district was south-west to north-east, it is possible that the reworked spores were transported from Antarctica.

Key words: Palynology, Permian, Devonian, Victorian, diamictite, *Emphanisporites*.

PLANT microfossils act as sedimentary particles in silt sized sediments because of their small size (20–200 μm), abundance, specific gravity, durability and chemical inertness (Playford & Dettmann 1996). They can be reworked into sedimentary rock, transported and redeposited. It is common in non-oxidising palaeo-environments to observe components of older palynomorph assemblages amongst younger, often better preserved palynomorphs, which provide the true age of the sedimentary sequence.

The morphologically distinct Middle to Late Devonian spore *Emphanisporites rotatus* McGregor emend. McGregor 1973 (McGregor 1973) is recorded herein for the first time in Victoria. The reworked specimens (Fig. 1) were recovered from an Early Permian glacigene sequence exposed at the Swing Bridge Section, Lerderderg River, Bacchus Marsh district. This report discusses their significance in relation to local geology and the possibility that they were sourced from Devonian sediments in Antarctica.

LOCALITY DESCRIPTION

Selwyn (1861) was first to recognise the glacigene nature of the sequences that crop out in the Bacchus Marsh area, west of Melbourne. Samples for the present palynological investigation were taken from a diamictite in the glacigene Bacchus Marsh Formation (Roberts 1984) of the Swing Bridge Section (O'Brien 1989; Archbold et al. 1997) at Morven Farm on the eastern bank of the Lerderderg River (Fig. 2). The stratigraphy of the sampled location (Fig. 3) consists of a relatively uniform sequence of poorly bedded, grey colored pebbly diamictite with sandstone lenses and imbricated boulders dipping towards the south. Figure 4 illustrates the diamictite and the sampling location within the Swing Bridge Section.

AGE OF THE GLACIGENE SEQUENCE

Historical evidence

Nineteenth Century discoveries of the fossil plant *Gangamopteris* (McCoy 1875) in the Bacchus Marsh area were, after long-running discussion and debate (see Archbold 1998), progressively assigned to the Permian Period. A Permo-Carboniferous age for the Bacchus Marsh Formation was deduced from the pioneering palynological work in the area by Virkki (1939, 1946). Subsequent authors have also concluded a Late Carboniferous–Early Permian age based upon palynological studies (Pant 1955; Pant & Mehra 1963; Douglas 1969). The marine invertebrate conulariid genus *Notoconularia* was recorded from other localities in the Bacchus Marsh area by Thomas (1969). Garratt (1969) recorded the brachiopod genus *Trigonotreta*, the bryozoan *Fenestella* and ?*Paraconularia*. Both reports indicated an Early Permian age for the two localities. Archbold (1991) described the *Trigonotreta* as a new species, *Trigonotreta victoriae*, and assigned it to the Early Permian (late Asselian or early Tastubian).

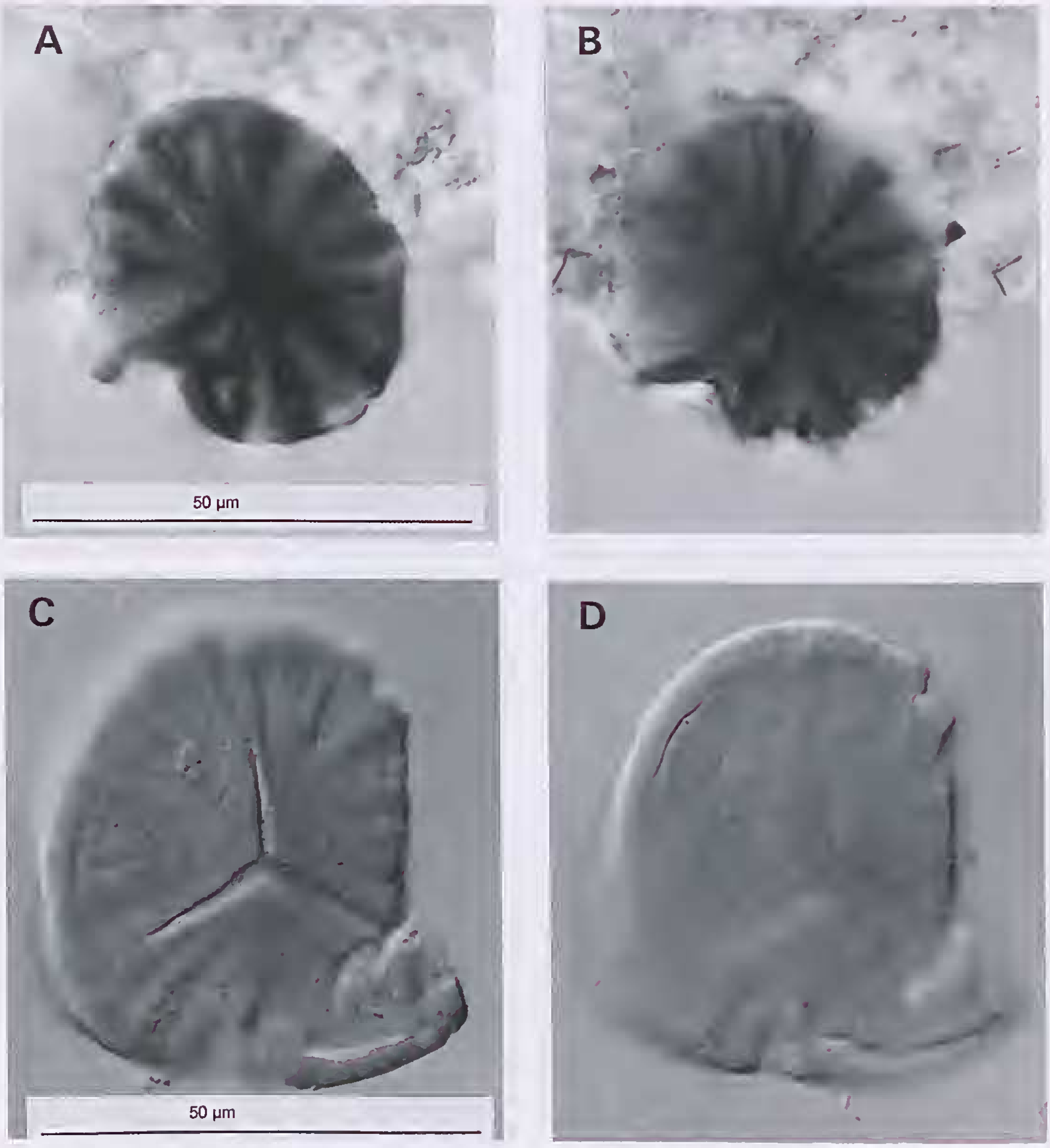


Fig. 1. Reworked *Emphanisporites rotatus* McGregor emend. McGregor 1973 from the Swing Bridge Section. A, proximal view; B, distal view (CPC36662). C, proximal view; D, distal view (CPC36664). *Note:* All palynomorphs in Figs 1, 5 and 6 were photographed using Differential Interference Contrast optics on an Olympus BX50 microscope system, No. 8L08051, housed at Deakin University. Illustrated palynomorphs are lodged with the Commonwealth Palaeontological Collection (CPC), housed at Geoscience Australia, Canberra. Reference numbers, prefixed CPC, are for that collection.

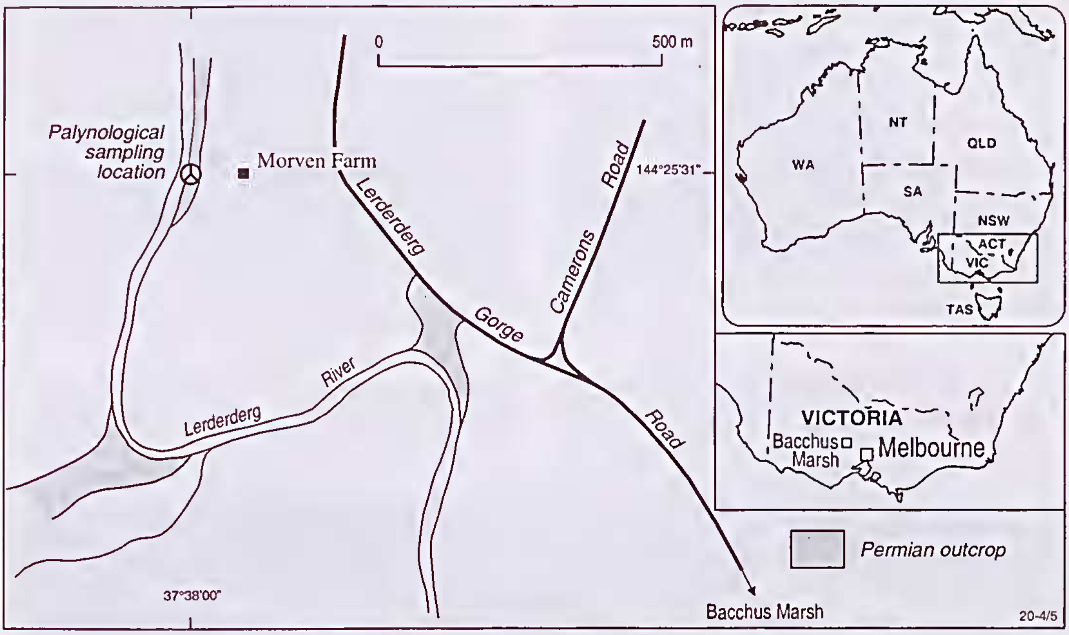


Fig. 2. Geological map of the Early Permian Bacchus Marsh Formation diamictite, Lerderderg River, Swing Bridge Section.

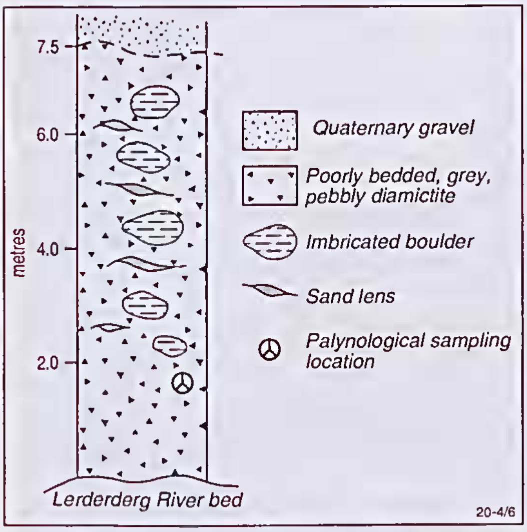


Fig. 3. Stratigraphical column at the Swing Bridge Section sampling location.

New palynological evidence

The present study has confirmed an Early Permian (Sakmarian) age for the diamictite sample from the Swing Bridge Section. The Swing Bridge Section assemblage belongs to the *Granulatisporites confluens* Oppel-zone of Foster & Waterhouse (1988). This widespread Gondwanan Oppel-zone is particularly indicative of the Tastubian substage throughout Gondwana (Archbold 2001). Taxa that are diagnostic of the *Granulatisporites confluens* Oppel-zone include *Microbaculispora tentula*, *Granulatisporites confluens*, *Cahenisaccites* sp. and *Horriditriletes ramosus* (Fig. 5), and *Plicatipollenites gondwanensis*, *Cycadopites follicularis* and *Protohaploxypinus* sp. (Fig. 6). Only key Permian taxa are described herein. A more complete record of the total Permian palynomorph assemblage at Bacchus Marsh will be discussed elsewhere.

The reworked Devonian elements are very rare in the assemblage, <0.5%, with only one species, *E. rotatus*, being identified. No other Devonian species were recognised with certainty.

DISTRIBUTION OF *EMPHANISPORITES ROTATUS*

McGregor & Playford (1992) have provided a comprehensive overview of the distribution of *Emphanisporites rotatus* in Australia. It is confined to sediments of Givetian–Frasnian age (late-Middle to early-Late Devonian). The species has been found in the following lithostratigraphical units: Gneudna Formation, Carnarvon Basin, Western Australia; Parke Siltstone, Amadeus Basin, Northern Territory; Gogo Formation and Pillara Limestone, Canning Basin, Western Australia; and the carbonaceous siltstone of the Eugenana beds, north-eastern Tasmania. In addition to McGregor & Playford's distribution, a single specimen, 'most closely comparable with *Emphanisporites rotatus*', from the Upper Etonvale Formation of the Adavale Basin, Queensland, was figured by de Jersey (1966).

Significantly *Emphanisporites rotatus* has not previously been recorded from Victoria. This raises the question of provenance of the specimens found at Bacchus Marsh.

PROVENANCE OF BACCHUS MARSH DEVONIAN SPORES

Ice movement during the Early Permian of south-east Australia

During the Early Permian, ice covered much of Victoria and western and north-eastern Tasmania (Brakel 1990). In the vicinity of Bacchus Marsh, ice flowed 'northward between 20° and 30°' (Crowell & Frakes 1971a). Crowell & Frakes (1971b) observed evidence of ice flow direction at the Morven Farm (Swing Bridge) Section as approximately N40°E. In the same section, Bowen & Thomas (1976) reported striations in bedrock at approximately N50°E. Brakel & Totterdell (1992)

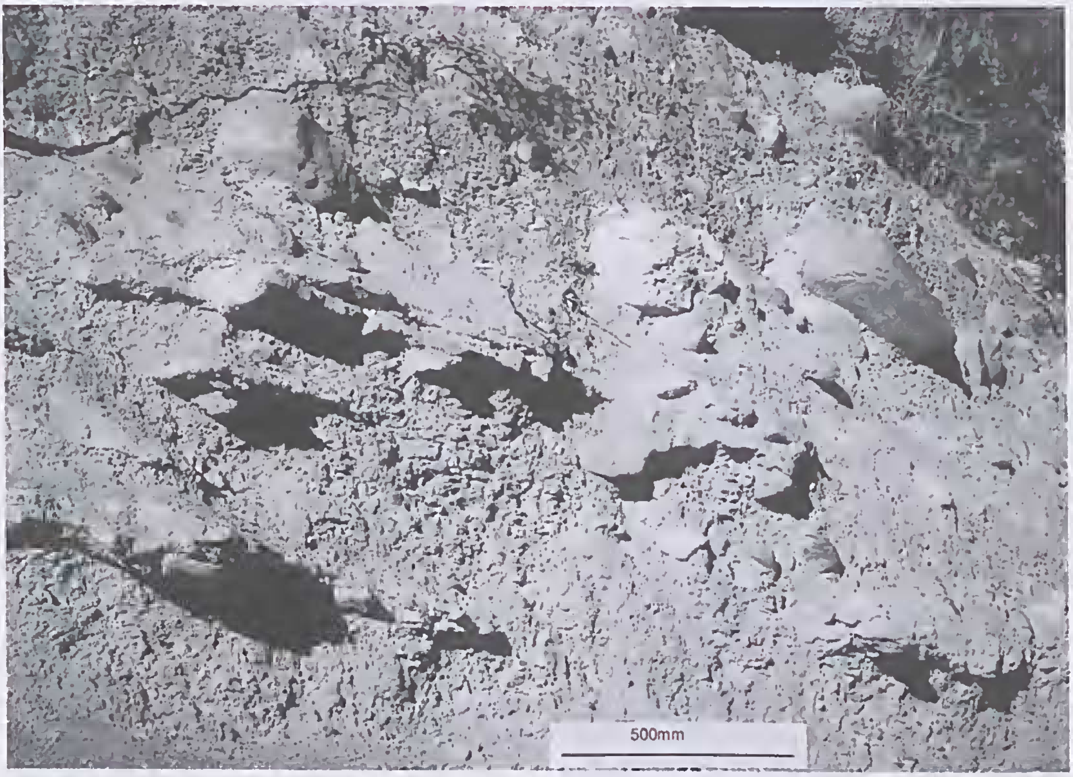
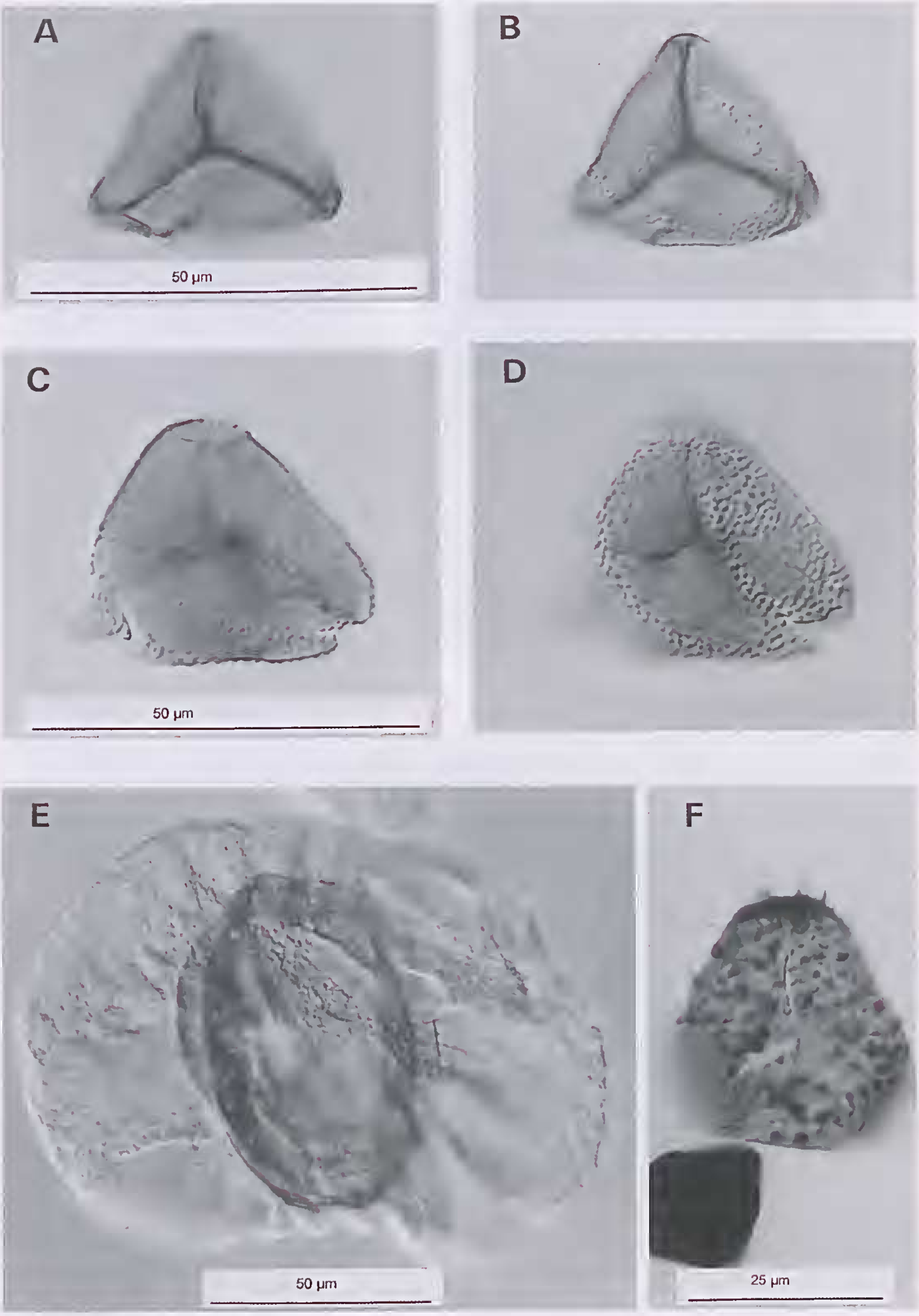


Fig. 4. Diamictite exposed on the eastern bank of the Lerderderg River, revealing imbricated boulders and dip to the southwards.

Fig. 5. Specimens from the *Granulatisporites confluens* Oppel-zone of the Swing Bridge Section. A, B, *Microbaculispora tentula* Tiwari 1965: A, proximal view; B, distal view (CPC36656). C, D, *Granulatisporites confluens* Archangelsky & Gammerro 1979: C, proximal view; D, distal view (CPC36657). E, *Cahenjasaccites* sp. (CPC36660). F, *Horriditriletes ramosus* (Balme & Hennelly) Bharadwaj & Salujha 1964 (CPC36658).


A
50 µm
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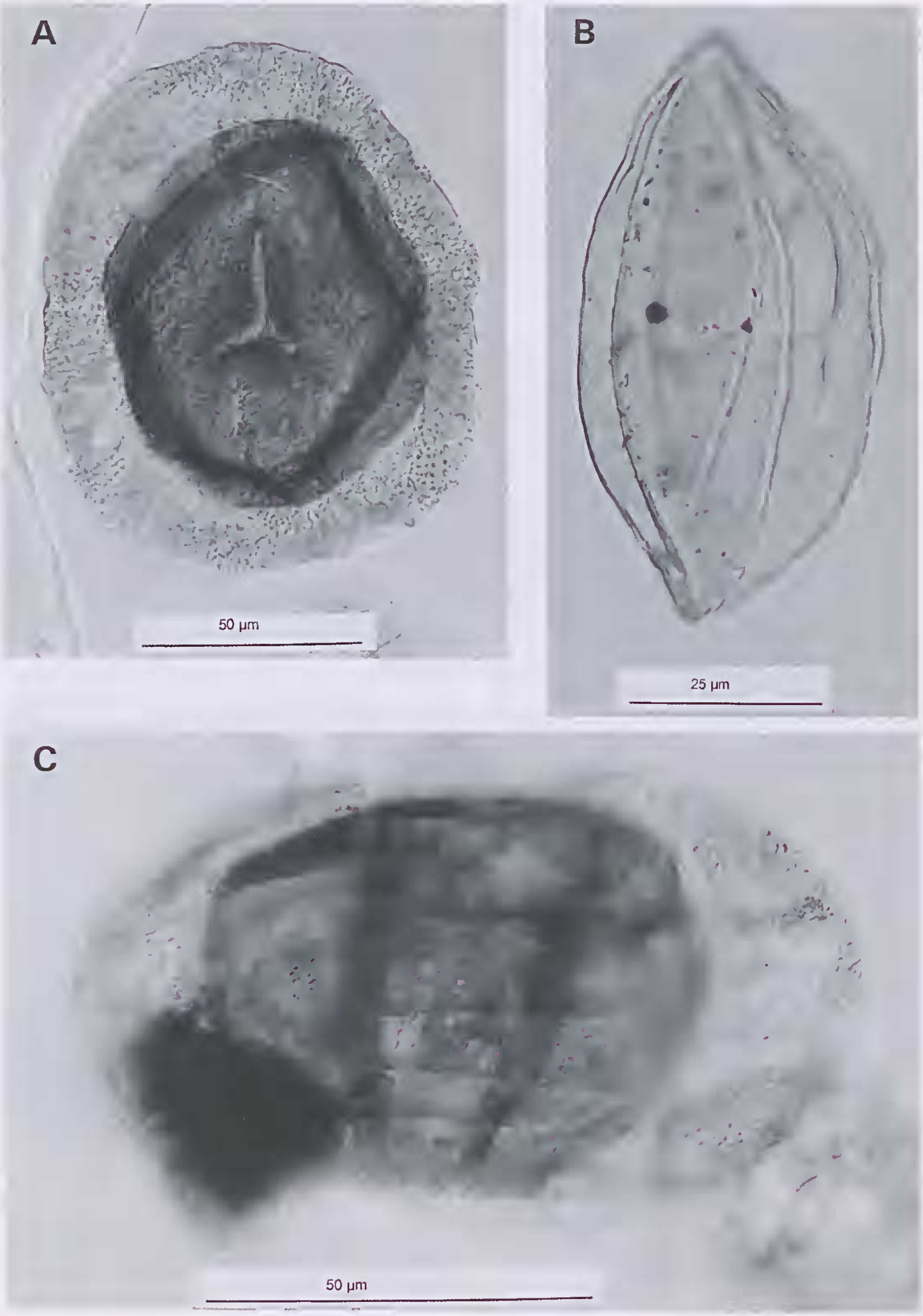
F
25 µm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deduced that, 'all ice directions are northerly; … ice encroaching into Tasmania, Victoria, and South Australia radiated out from a centre in northern Victoria Land in adjacent Antarctica'.

The above records of direction of ice movement in the vicinity of Bacchus Marsh and at the Swing Bridge Section include a range of values. The evidence indicates that ice movement was from the south-west to the north-east at this locality. This ice would have transported the appropriate Devonian aged rocks containing the reworked spores.

Victorian Givetian–Frasnian sedimentary rocks

Marsden (1976) stated that during the Middle and Late Devonian, 'only very minor sedimentation occurred in the Central Victorian Province', which includes the Bacchus Marsh area. Approximately 100 km to the north-east of Bacchus Marsh, the Mount Howitt Province contains extensive Late Devonian (Late Givetian to Famennian) sediments (Marsden1976).

All Devonian sedimentary rocks of appropriate age in Victoria are north and east of the Bacchus Marsh locality, while the Permian ice flow was from south-west to north-east. The possibility that Devonian spores, originating from appropriately aged rocks from within Victoria, were transported to Bacchus Marsh by ice movement, appears highly unlikely.

The evidence presented here suggests a non-local origin for the reworked spores. This contrasts with the conclusion reached by Harris & McGowran (1971) who also reported recycled Devonian palynomorphs from diamictites of the same age from the Cape Jervis Beds, Troubridge Basin, South Australia (see also Gilby & Foster 1988; Foster 1974). Harris & McGowran's conclusion of a local origin for the Devonian spores was based upon the preservation of the recycled forms, including rare specimens of *Ancyrospora* sp. This taxon was not observed during the present study.

Southern sources of Devonian rocks

Banks & Burns (1962) assigned spores to the genus *Radiaspora*, now regarded as congeneric with *Emphanisporites* (Balme 1964; McGregor 1973), from Upper Middle Devonian cave deposits at Eugenana, north-eastern Tasmania.

In Antarctica, *Emphanisporites* has been observed in Devonian assemblages from south Victoria Land, Beacon Valley, Aztec Siltstone (Helby & McElroy 1969) and Terra Cotta Siltstone (Kyle 1977), as well as from the Transantarctic Mountains, Ohio Range, Horlick Formation (Kemp 1972).

An Early Permian (Sakmarian) palaeogeographical reconstruction of Antarctica and Australia (Fig. 7), supports our suggestion that *Emphanisporites* spores found at Bacchus Marsh were sourced from the Devonian successions within the Transantarctic Mountains of Antarctica. During the Early Permian, ice movement could have transported the rock in a north-easterly direction to deposit the spores in diamictite at Bacchus Marsh. A less likely source for the reworked spores may have been north-eastern Tasmania.

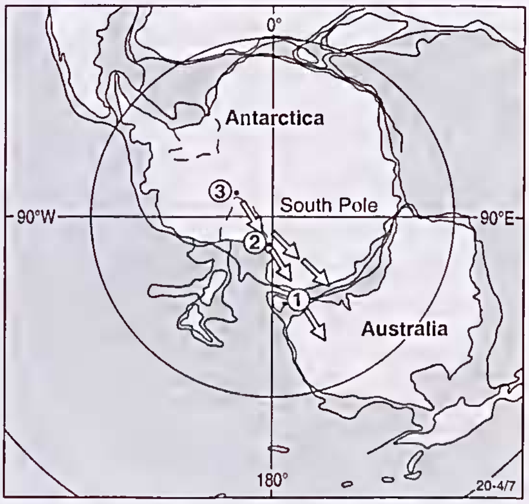

Fig. 7. Early Permian (Sakmarian) palaeogeographical reconstruction showing locations of possible palynomorph-bearing Devonian source rock in Tasmania and Antarctica and the path of ice transportation to south-eastern Australia. 1, north-eastern Tasmania (Eugenana beds); 2, south Victoria Land (Aztec Siltstone and Terra Cotta Siltstone); 3, Transantarctic Mountains, Ohio Range (Horlick Formation). Reconstruction after Truswell (1991).

Fig. 6. Specimens from the *Granulatisporites confluens* Oppel-zone of the Swing Bridge Section. A, *Plicatipollenites gondwanensis* (Balme & Hennelly) Lele 1964 (CPC36663). B, *Cycadopites follicularis* Wilson & Webster 1964 (CPC36659). C, *Protohaploxypinus* sp. (CPC36661).

CONCLUSION

This record of *Emphanisporites rotatus* from the Early Permian Bacchus Marsh Formation at the Swing Bridge Section represents the first report of the late-Middle to early-Late Devonian species in Victoria. Evidence of Early Permian southerly to northerly ice movement from Antarctica to southern Australia strongly suggests an Antarctic source for this reworked species at Bacchus Marsh.

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APPENDIX

Systematic palaeontology

Genus *Emphanisporites* McGregor 1961

Type species (by original designation). *Emphanisporites rotatus* McGregor 1961.

Emphanisporites rotatus McGregor emend. McGregor 1973: fig. 1A–D.

Partial synonymy (see McGregor 1973: 46–47 for complete listing).

1960 *Radiaspora* sp. A.—Balme: p. 6, pl. 1, figs 11, 12.
1961 *Emphanisporites rotatus* McGregor: p. 3, pl. 1, figs 1–4.
?1962 '*Radiaspora*'—Banks & Burns: (no figs and no description).
1964 *Radiaspora* sp.—Balme: pl. 1, fig. 1. (no description).
1966 *Emphanisporites* sp.—de Jersey: p. 14, pl. 6, fig. 3.
1969 *Emphanisporites* sp.—Helby & McElroy: fig. 3D (no description).
1971 *Emphanisporites* sp. cf. *E. rotatus*—Harris & McGowran: fig. 1 (no description).
1972 *Emphanisporites rotatus*—Kemp: pl. 55, figs 1–3 (no description).
1973 *Emphanisporites rotatus*—McGregor emend.: p. 47, pl. 6, figs 9–13.
?1977 *Emphanisporites* spp.—Kyle: (no figs and no description).

Description (from McGregor 1973: 47)

'Trilete miospores, amb broadly subtriangular to circular. Sutures simple or with low, narrow labra, extend to or nearly to equator. Distal hemisphere unsculptured; proximal face with 4 to 10 radial, spoke like ridges in each interradial sector. Ridges widest towards the equator, narrowing proximally and commonly fused to form a thick, slightly darker zone around the proximal pole. On some specimens there may be little or no merging of the ridges at the pole, and on some the ribs may extend only part way towards the pole, the apex of the spore being devoid of ridges or other sculpture. Ridges may bifurcate or trifurcate towards the equator. Laesurae commonly flanked by ridges. Wall about 1.5–3 μm thick distally, and on some specimens 1–2 μm thicker (cingulate) in a narrow zone at the equatorial region of the distal hemisphere.

Curvaturae have been detected on some specimens, but they usually are not evident because the rays are long, and the spore rarely is compressed laterally. Diameter 32–84 μm, mean 54 μm.'

Remarks

The two figured specimens conform to the range within the above diagnosis for *E. rotatus*. Their diameters are 54 μm and 42 μm.

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